Acceptance Data Package Tracker Readout Electronics (T-Electronics) of the AMS-02 Experiment

Main document

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Document history:

Version	Date	Changes	Pages affected
1	23.11.2009	First Build	all

LIST OF ACRONYMS

T-Crate	Electronics Crate for Readout and Control Boards for TRD
TPD	Power Distribution Box for T Electronics
TxPD	Power Distribution Box for T Electronics and another AMS sub-detector
TSPD	Power Distribution Box for T Electronics and S Electronics
TMPD	Power Distribution Box for T Electronics and M Electronics
TDR2	Data Reduction board for Tracker
JINF	AMS-02 Interface board
S9011AT	Controller board for TPD electronics
S9011B	28V input filter of TPD
S9053	DC/DC Converter for 3.3V digital power
S9051	DC/DC converter for 5.6V and +/- 2.5Vfront-end power supply
S9055	DC/DC converter for +/-6 and 120V power for high voltage generators
TPSFE	Tracker Power Supply for the silicon modules Front-end Electronics
TBS	Tracker silicon modules Bias voltage Supply
TFS	Tracker front-end simulator
ESS	Environmental Stress Screening (Thermal Cycle and Vibration Test)
TVT	Thermo-Vacuum Test
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
DSP	Digital Signal Processor
FPGA	Field Programmable Gate Array

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PREFACE

The acceptance data package is requested by the Alpha Magnetic Spectrometer (AMS) project management for all of the collaborator's hardware that will be integrated into the AMS-02 payload at CERN in Geneva. Only completed review of the ADP by NASA allows integration of described hardware onto the payload integration hardware provided by NASA.
This package includes acceptance data for readout electronics of the tracker in the eight T-Crates as well as its power distribution system in the eight TxPD boxes.
Current integration schedule foresees mounting of these electronics crates to the WAKE and RAM main radiators and subsequent integration of radiators to the USS for November 2009.
This is first version of the acceptance data package main document for described hardware.

I. INTRODUCTION

Document purpose

This is the main document of the AMS-02 acceptance data package (ADP) for electronics subsystem for readout and control of the silicon tracker. The allocation in AMS-02 as part of the tracker is indicated by the letter 'T' in front of its component identifiers (e.g. T-Crate, which houses the tracker electronics), thus contents of this document describes T-electronics.
The ADP contains documentation of the various steps of verification of space qualification and compliance with regulation for operation on board the ISS. These are environmental stress screening, thermo-vacuum test and EMI/EMC test in qualification phase, acceptance testing of flight hardware and documentation of assembly procedures.
In the following an overview of the T-electronics will be given.

The tracker crate and its power supplies

The tracker crate is composed of the following 19 boards:

Name	*Quantity*	*Purpose*
TDR2	12	Hosts two Tracker Data Reduction circuits
TPSFE	4	Tracker Power Supply for the Font End electronics of three TDR2
TBS	2	Tracker Bias Supply for six TDR2 boards
Jinf	1	Hosts two Jinf circuits

Figure 1 illustrates the tracker crate structure, boards are indexed from 1 to 19.

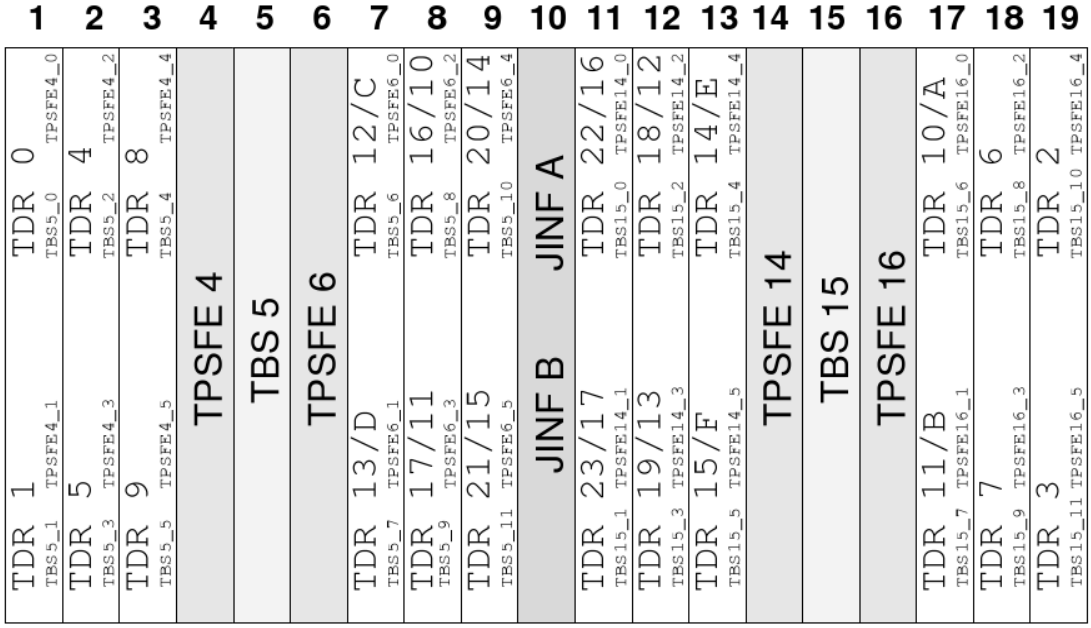

Figure 1: Tracker crate composition. One TPSFE is connected to three TDR2 boards, one TBS is connected to six TDR2 boards.

The TPD (Tracker Power Distributor) is the box providing the various voltages to the T-Crate. It also includes a control board which is managed by the JINF, using the LeCroy protocol. The TPD is composed of the following boards:

Name	***Quantity***	***Purpose***
S9051	4	Provides ±2.5 V (S and K) to one TPSFE, 5.6 V (S and K) to three TDR2
S9053	2	Provides 3.3 V (digital power supply)
S9055	2	Provides 120 V and ±6 V to one TBS
S9011AT	1	Control of the DC-DC converter boards, interface with Jinf
S9011B	1	28V filters

Some aspects of the power supply are interesting to note:

- To one S9051 corresponds one TPSFE;
- To one S9055 corresponds one TBS;
- Board S9053_0 provides the digital power supply to boards 1 to 9 and Jinf A;
- Board S9053_1 provides the digital power supply to boards 11 to 19 and Jinf B;

Each T-Crate is powered by its own power distribution box. For space occupation and weight

limitation reasons, some of the Tracker power distribution boxes also contain DC-DC converters for other sub-detector electronics. Following table summarizes the power distribution and crate relation (see also figure 2).

Power distributor	*Corresponding crate(s)*
TPD0	T0
TSPD1	T1 and S0
TMPD2	T2 and M
TSPD3	T3 and S1
TSPD4	T4 and S2
TPD5	T5
TSPD6	T6 and S3
TPD7	T7
TPD8 (Flight Spare)	T8 (Flight Spare)

Location in AMS-02

The complete tracker readout electronics consists of eight T-Crates and eight TxPD-boxes, which are mounted on both WAKE and RAM side of the main radiators. In the following flight model of the T-Crate and TxPD boxes are named depending on their location on the radiators.

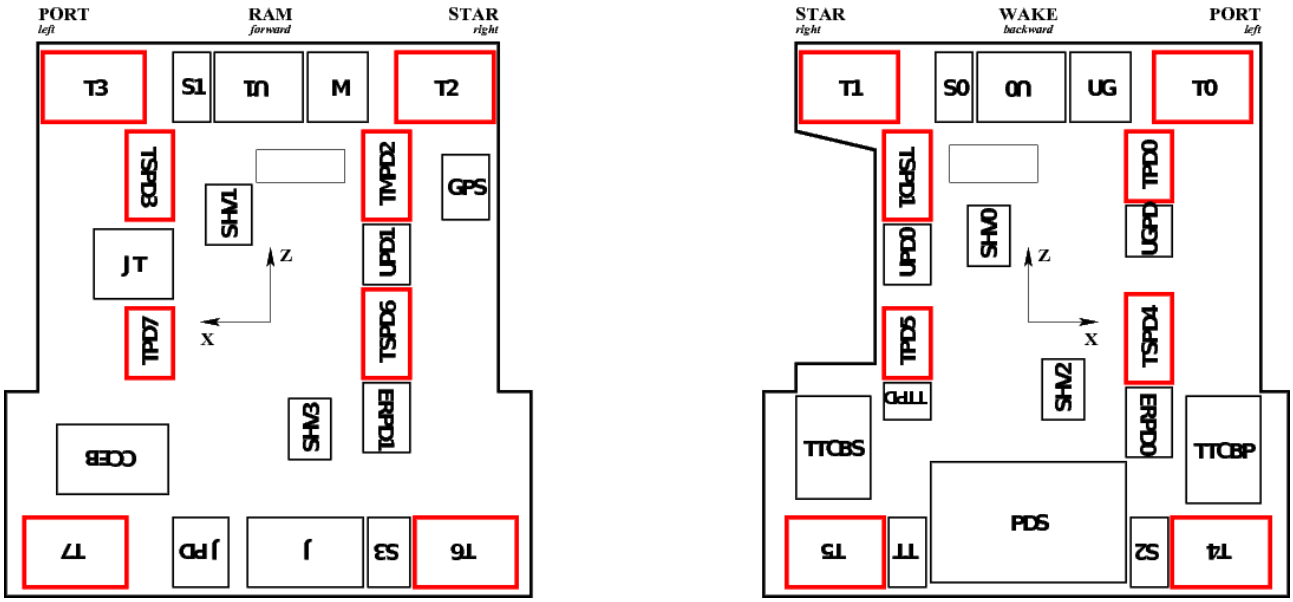

Figure 2: Location of the T-Crates and their corresponding TxPD on the RAM and WAKE sides of the radiators.

II. MECHANICAL DESIGN

Mechanics parts of T-Crate and TxPD box are made of aluminum 7075 T7351. The crate walls are machined out of single aluminum pieces. All surfaces are hardened by surface treatment. Anodizing, when no electrical and thermal contact is desired, otherwise Alodine is applied. Besides the mechanical stability and the performance under vibration, the thermal transfer capability plays a major rule. The heat generated on the electronics boards has to be removed. This is accomplished by using wedge locks, which are mounted close to the right and left side of each board on metallized areas. After the board is inserted into the crate, the wedge locks are splayed by adjusting a screw to establish thermal contact to the crate wall. The mechanical design drawings were created by CGS. Machining and surface treatment of flight and flight-spare parts was done at CSIST, Taiwan. Assembly of all mechanical parts was done during flight assembly phase under supervision of project responsible person, which is described in chapter FLIGHT ASSEMBLY, where links to control sheets and torque record table are given.

See T-Crate assembly drawing Rev A, 21 March 2006.

III. QUALIFICATION PHASE (QM2)

A complete set of qualification model (QM2) T-Crate and (QM2) TPD box was built in order to perform functional tests with the detector and to carry out the space qualification procedure. In the following summary of performed tests and their results are summarized and full documentation files are linked.
The development and production of the Tracker electronics boards was carried out in four different steps. In the first step the Engineering Model (EM) has been produced followed by the qualification model 1 (QM1) in the next step. Both steps were produced by the company CAEN. After the QM1-production step the electronics was supposed to be considered bug free and the next steps could be started. The boards of step three were called the Qualification Model 2 (QM2) and the boards of step four were the final Flight model (FM) including Flight Spare (FS), both produced by CSIST in Taiwan.

This section includes crate level test of QM2 hardware during the qualification procedure, which are the final tests before flight production can be initialized. Here the performance of the complete system is tested in interaction of the individual components. Results of preceding test on board level and/or in EM phase can be presented on request, but are not included in this package.

Environmental stress screening

On crate level the environmental stress screening (ESS) includes three different phases of testing, namely thermal cycling, vibration test and final thermal cycles. The common AMS-02 profile for these tests was used and is shown in figure 3.

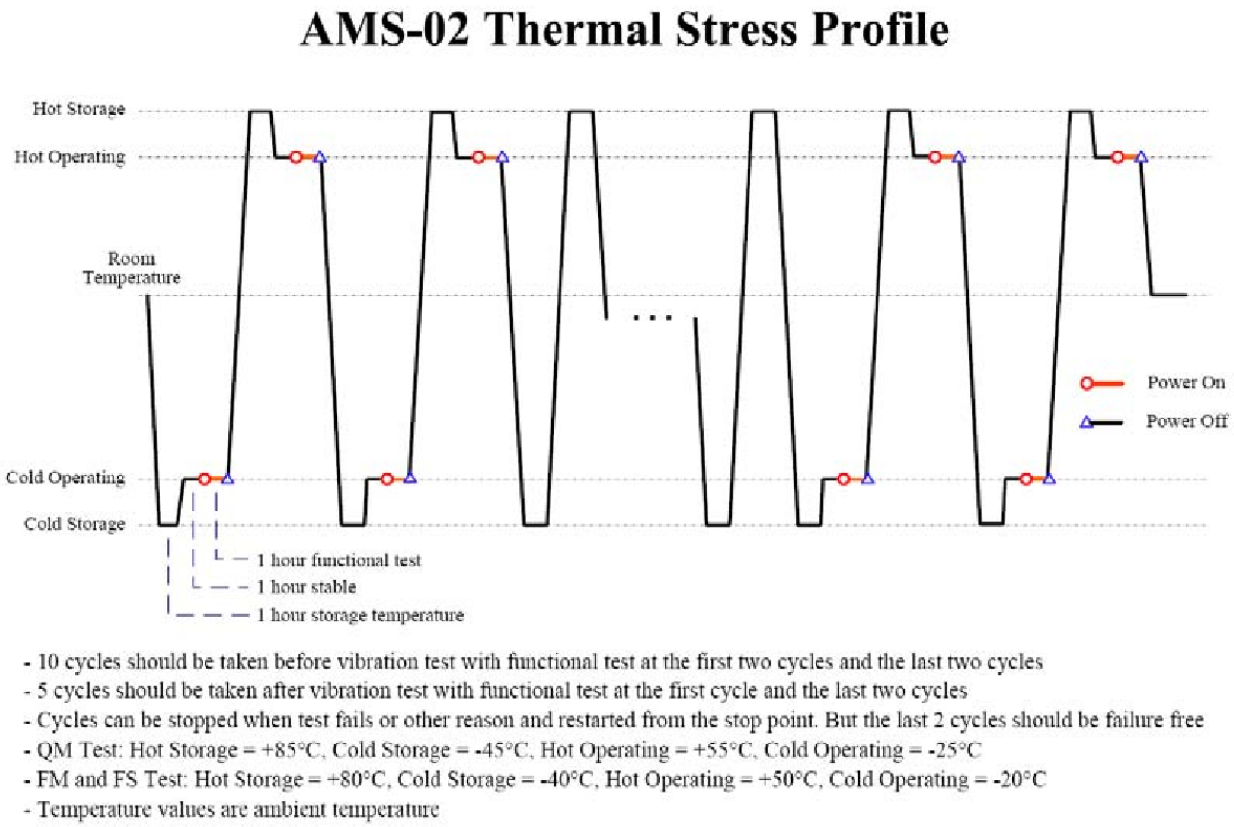

Figure 3: Thermal stress profile for the QM and FM crates.

During temperature cycling the temperature remains constant at the cold and hot storage temperatures for one hour before being conducted to the hot and cold operating temperatures. There the temperature is kept constant for again one hour. As soon as the operational temperature is reached again, the electronics is switched on and functional tests have to be performed. Ten cycles should be performed with functional tests during the first two cycles and the last two cycles before entering the vibration test. After the vibration test, five cycles should be taken with functional tests during the first cycle and the last two cycles. The cycles can be stopped whenever a test fails or for any other reason. But to successfully accomplish this test, the last two cycles should be failure free. The four temperature levels in QM2 and FM/FS are given in the following table.

	Hot storage	***Hot operational***	***Cold operational***	***Cold storage***
QM2	+85°C	+55°C	-25°C	-45°C
FM	+80°C	+50°C	-20°C	-40°C

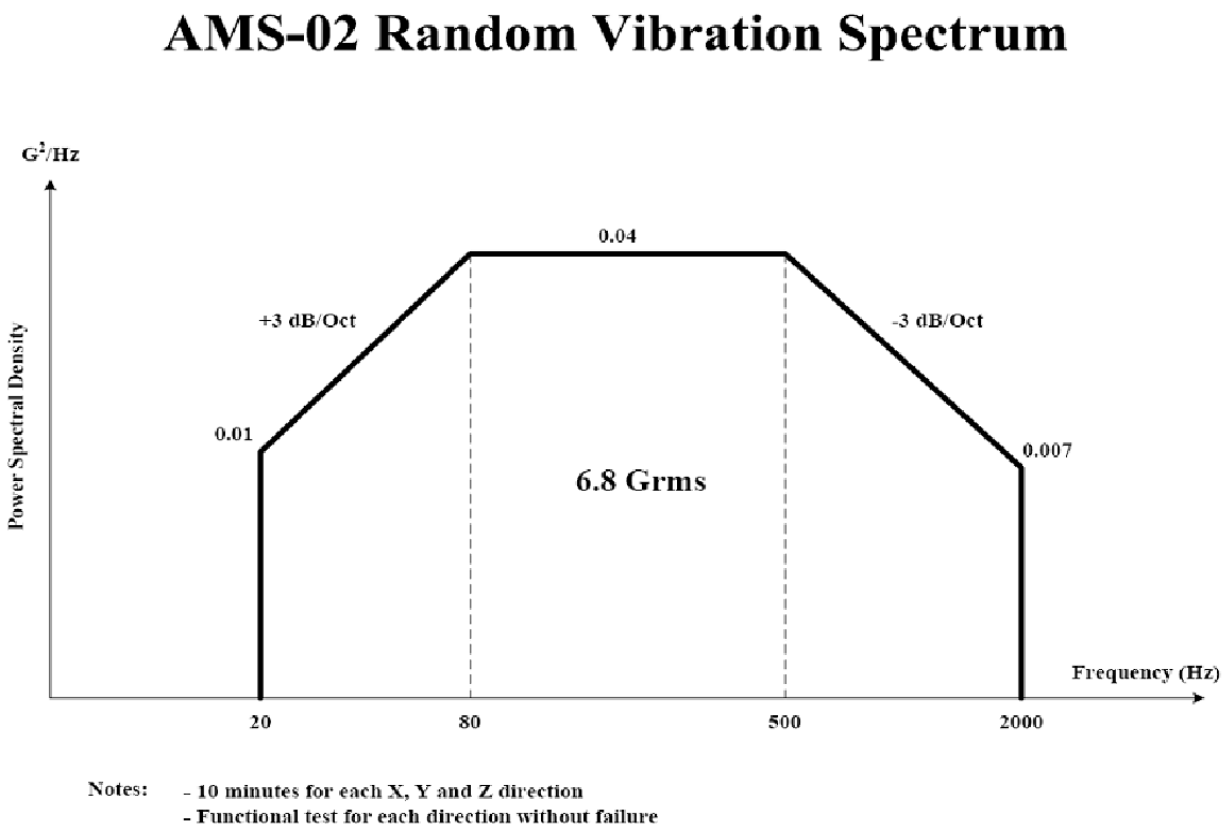

Figure 4: Random vibration spectrum used for the QM T-Crate and TPD.

During vibration test the standard power spectral density is applied to the hardware according to shown figure. For QM2 qualification test this vibration spectrum is applied for 10 minutes in X, Y and Z direction, while powering the hardware and performing functional tests. During vibration constant tests are carried out in order to identify latent defects and manufacturing flaws in electronics hardware. After the vibration a more detailed test is performed in order to identify possible permanent damage to the system. During Crate ESS no hardware problems showed up.

See test report file: *tracker_QM_ESS_TVT_report.pdf*

Electromagnetic interference and compatibility test

The electromagnetic compatibility and interference test is performed according to requirements for electronic equipment being used in the International Space Station. First part of the test was successfully passed at CSIST facilities in Taiwan, including conducted susceptibility test sinusoidal disturbances CS01/CS02 and spikes CS06, conducted emission during switch-on CE01 and during operation CE03 and radiated susceptibility of spikes RS02. Radiated susceptibility of sinusoidal radiation RS03 and radiation emission during operation RE02 were repeated after hardware modification at Terni facilities in Italy and passed.
The EMI/EMC test at CSIST showed failure of the system control during radiated susceptibility test RS03 when no additional shielding on crate to box cables is applied. With proper shielding all tests were passed. A second EMI/EMC test in Terni was performed with modifications to grounding scheme of the system and new firmware. This test was passed without additional shielding.

See EMC test report from CSIT file: *EMCRPT-T-TPD.pdf*
See measurements at SERMS file: *tracker_emi_terni.pdf*

Observed were infrequent errors of AMSWire-communication in RS03 test at 250MHz/300MHz@60V/m field during operation of T-system. Equal observation was made also with U-system in a previous test. This is not a critical failure, since in case of failed transmission the command can be resent and the system stays controlled. Further investigation shows this problem is avoidable by shielding JINF front panels up to fields of 200V/m by Aluminum tape.

Thermal vacuum test

The thermal vacuum test was done according to AMS-02 hardware test requirements. The common AMS-02 profile for these tests applies. The test was performed at SERMS facilities in Terni, Italy. No problems during operational phases of the system were found. All tests are passed successfully.

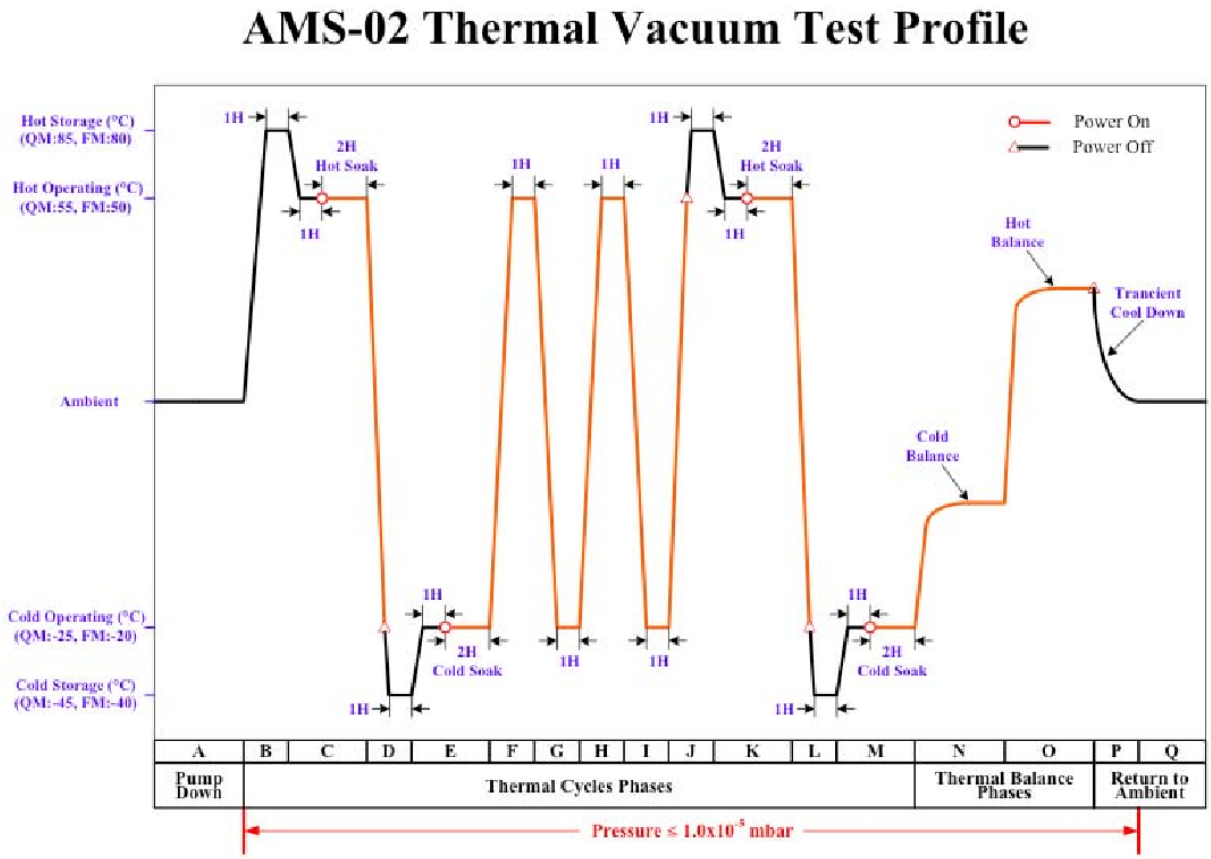

Figure 5: Thermal vacuum test profile used for the QM TPD and T-Crate.

See qualification test report: *tracker_QM_ESS_TVT_report.pdf*

IV. FLIGHT HARDWARE ASSEMBLY

The assembly of Tracker readout electronics can be divided into assembly of three separate articles, the T-Crate, the TxPD-Box and a set of Cables connecting TxPD and T-Crate. In flight production nine T-Crates, nine TxPDs and nine sets of cables TxPD-TCRATE were assembled.
Manufacturing and assembly of all components was done at CSIST workshop in Taiwan in the summer 2007.

See TPD assembly documentation file:*TPD_Assemblyv2.pdf*

Production and assembly documentation

During assembly important work steps are recorded in separate documents listed below. All documents are part of the production control document package, which can be presented on request, but are not included in this package.

Production control sheet

The production control sheets document each step if assembly at CSIST workshop. This covers production and assembly of electronics boards and assembly of the crate mechanics. Each work step is stamped or signed by responsible person. Main steps on board level are:

- PCA (mounting of component to the PCB)
- Functional test
- Conformal coating
- mechanical parts assembly
- board ESS
- functional test
- crate assembly
- crate test

Main steps on crate level are:

- crate assembly
- functional test
- crate ESS
- final functional test

Only components with duly completed control sheet are approved to leave CSIST workshop.

Serial number record

Each manufactured board has a serial number printed on the PCB below the conformal coating. It consists of the Chinese year of production and a running number, e.g. TDR2 95001. During crate and box assembly serial numbers of inserted boards are recorded, since they cannot be identified when assembled in the crate. The serial number record table is part of the control document package.

Torque table record

Running and seating torque is recorded for all screws with self-locking helicoil backoff prevention. Separate helicoil screws map is given for each T-Crate and TxPD with identifier for each helicoil. The torque table record is part of the control document package.

V. FLIGHT HARDWARE ACCEPTANCE TEST

The flight hardware acceptance testing can be divided into three steps. First step is the board level acceptance test performed at CSIST in Taiwan. Second step is crate level ESS, which is carried out at CSIST facilities. Last step is the acceptance test thermal vacuum test done at SERMS facilities in Terni, Italy.
Board level tests are done in order to identify problems during production and assembly of electronics boards. Part exchange is easy since full functional tests are performed before conformal coating for the boards is applied. Several minor problems were identified and described in non-conformance reports.

See appendix for test documents and non-conformance reports:
file: ***AMS02-NCR-E-T-allv2.pdf***
file: ***BoardControl_TDR2.pdf***

On crate level the environmental stress screening (ESS) includes three different phases of testing, namely thermal cycling, vibration test and final thermal cycles. The common AMS-02 profile for these tests was used with reduced stress for flight hardware. Test procedure is equally in depth as during QM2 tests.
The thermal vacuum test was done according to AMS-02 hardware test requirements. The common AMS-02 profile for these tests applies with reduced stress for flight hardware. The test was performed at SERMS facilities in Terni, Italy.

See appendix for FM crates test report file: ***tracker_FM_ESS_TVT_report.pdf***
See appendix for SERMS report file: ***ENVRPT28-S3014R-10NOV2K9.pdf***